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The ILLUMINATING ENGINEER

ELECTRICITY · ACETYLENE · OIL · GAS

Edited by LEON GASTER

10/6 Yearly. THE JOURNAL OF SCIENTIFIC ILLUMINATION. 1/- a Copy.

OFFICIAL ORGAN OF THE
Illuminating Engineering Society.
(Founded in London 1909.)

This number contains the complete account of the *Discussion* on ***"Some Future Possibilities in the Design of Instruments for measuring Illumination"*** (with special reference to photometers depending on physical and chemical methods), at the meeting of The Illuminating Engineering Society on February 22nd, 1916.

Other Articles include :—

A YEAR'S PROGRESS IN ILLUMINATING ENGINEERING *(continued)*.

TOPICAL AND INDUSTRIAL SECTION, &c.

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EDITORIAL.

Industrial Research and the Scientific and Technical Press.

An important discussion on "The Sphere of the Scientific and Technical Press in relation to Technical Education and Industrial Research" took place at the last meeting of the Circle of Scientific, Technical and Trade Journalists on March 14th, at the Hall of the Institute of Journalists. Introductory addresses were delivered by Dr. W. Garnett, late Educational Advisor to the L.C.C., and Mr. A. P. M. Fleming, of the British Westinghouse Electrical Manufacturing Co., who has made a special study of Industrial Research.

The object of the meeting was to consider in what ways the technical and scientific press can best extend its services in bringing the benefits of technical education and industrial research more prominently before the notice of manufacturers and the public. Before considering this matter it was thought desirable to obtain a general survey of the present position, and the addresses of Dr. Garnett and Mr. Fleming (which we contemplate publishing in full, together with the valuable ensuing discussion, in a coming number of this journal) furnish a clear exposition of the subject.

The imperative necessity of organising the scientific and technical resources of the country in a more scientific manner is now widely recognised. Among the various steps taken in this direction one of the most important is undoubtedly the creation of a Committee of the Privy Council charged with the duty of developing Industrial Research, and it is significant that the grant allotted to its Advisory Council for research during the present year, although still far from adequate, has been substantially increased. This is rightly recognised as a direction in which money well spent now will be amply repaid in the future.

The promotion of unity of effort on the part of the various Associations and Societies interested in applied science is most important. We are glad to see that the Royal Society is considering this matter, and that at a recent conference it was decided to form a Board to advise the Government on any branch of scientific enquiry that may be brought before it.

In the lighting industry we believe that there are many problems which would well repay further investigation, and this matter is to be dealt with by a special committee of the Illuminating Engineering Society, and also at a coming meeting of the Society on May 9th.

One of the chief needs at the present time is undoubtedly to awaken a deeper appreciation of the value of science on the part of the general public. In this respect we believe that the scientific and technical press, which offers a unique channel for the dissemination of information amongst the manufacturers of the country, could do good service, and that impartial suggestions and criticism emanating from this source would be very helpful. The best method of utilising this assistance is a matter for further deliberation and doubtless the Committee of the Council on Industrial Research will consider how the efforts of the State can best be seconded by the press of the country.

For the moment we only wish to put on record the desire of the Circle of Scientific, Technical and Trade Journalists to be of assistance—a desire which is fully expressed in the following resolution, passed at the meeting on March 14th :—

" That this meeting recognises that Technical Education and Industrial Research are of great benefit to the manufacturers of this country.

" That the Circle of Scientific, Technical and Trade Journalists is prepared to assist the promotion of unity of effort on the part of the various Associations and Committees engaged in the study of the subject.

" That the Scientific and Technical Press be used as a medium for the dissemination of information of value to the industries of the country, thus bringing about a fuller appreciation of the value of Technical Education and Industrial Research."

No doubt the movement thus commenced for promoting the concerted action of the press in dealing with these important matters will lead to useful results—especially in the direction of promoting unity of effort on the part of the various organisations now discussing these problems.

Future Possibilities in the Design of Instruments for Measuring Illumination

The measurement of light and illumination has been frequently discussed by the Illuminating Engineering Society in the past, and on each occasion distinct advances towards the simplification of apparatus for this purpose were recorded. The measurement of illumination is undoubtedly a much more familiar process than it was a few years ago, and the progress in this respect has doubtless influenced the tendency towards greater precision in studying lighting requirements. The definite values suggested in the recently issued Home Office Report on Lighting in Factories and Workshops furnish an illustration of the fact that our ideas regarding these requirements are becoming crystallised, and that therefore the provision of instruments for testing whether these ideas are realised in practice is now a matter of more than academic importance.

It was therefore thought that the time was ripe for a general survey of the subject. The discussion arranged before the Society on February 22nd was productive of much useful information. There was a general recognition that for many purposes apparatus even simpler and more convenient than that available at present would be useful. Instruments of this type need not be extremely accurate; they would be used merely to furnish a rough working idea of the illumination in a room or factory and should be capable of being used by managers and others who are not necessarily experts in photometry.

On the other hand, we agree with the Chairman (Mr. Goodenough) in thinking that a distinction must be drawn between instruments which are intended for general experimental work, where a fair margin of error is permissible, and apparatus intended for use in determining whether a lighting contract has been complied with, and whether a penalty for failing to provide the requisite illumination is to be imposed. No doubt in such cases accuracy is the chief essential and it might be desirable to employ a more complex and finished form of instrument in order to reduce the margin of error within desired limits.

In the course of the discussion some interesting suggestions for the simplification of illumination photometers were made by Mr. A. Cunnington and Mr. Trezise. The former showed a rough model of what may be termed an " illumination-gauge " enabling a reading of illumination to be obtained by mere inspection, and without its being necessary to manipulate the parts of the instrument in order to secure photometric balance. It will be recalled that an instrument having this quality was suggested by Mr. Haydn T. Harrison at a meeting of the Society in 1910, and it is possible that a very simple and cheap instrument might be produced on these lines for rough work.

Mr. Trezise exhibited a series of models of experimental photometers, an interesting feature of which was the use of a special screen, utilising an inclined piece of white glass cut with a diamond; this appeared to be highly sensitive and to enable exact photometric balance to be readily obtained. In several of these instruments the method was adopted of bringing the lamp very close to the illuminated screen, thus rendering it possible to obtain a wide range of readings and to reduce the instrument within small dimensions.

Passing on to other points in the discussion we should like to refer to the useful information afforded regarding the possibilities of " direct-reading " photometers based on physical and chemical methods, a most

interesting account of some of the work done on the Continent and in the United States being given by Prof. Féry (Paris), Dr. Ives (Philadelphia, U.S.A.) and Dr. Coblentz (Washington, U.S.A.). These contributions furnish a striking instance of the value of the international connections of the Society.

During recent years the possibility of using selenium and photo-electrical cells for photometry has been the subject of much careful study. The experimental difficulties are no doubt great but our knowledge of the peculiarities of such cells has been considerably increased, and it is conceivable that in the future these obstacles may be overcome and that an instrument resembling a form of " artificial eye " may yet be developed Meantime, it is interesting to observe that selenium has already been in use for the automatic control of lighting systems, the lamps being automatically turned on in darkness, but extinguished in daylight. Even at the present stage it seems well worth consideration if an apparatus capable of turning on the artificial light in schools and factories when the natural illumination has fallen to a prescribed value could not be worked out.

The use of photographic methods for photometry was discussed by several contributors, but at present it seems evident that this method, while useful for purely relative results with one and the same illuminant and in special researches on very faint or transient light-effects, is not very suitable for comparing different types of lamps

In some respects the most hopeful type of direct-reading photometer is that depending on the use of thermopiles which react to radiated energy of all kinds. In this case it is necessary to create an " artificial eye " by obstructing the radiation which is non-luminous or to which the eye is comparatively insensitive. Accordingly special prismatic devices or coloured solutions have been employed, and it appears that in this way very consistent results have already been obtained in the laboratory, even when lamps differing considerably in the colour of their light have been compared. One would imagine that for laboratory work such instruments would have special fields of utility, especially in confirming experimental work on standards or in recording very small and scarcely detectable changes in candlepower. Every photometric worker knows how easily such work may be upset by personal peculiarities in the eyes of the persons reading the photometer, and how results have to be checked again and again before they can be accepted as correct. In such cases a confirmatory experiment with a photometer might be of great value.

On the other hand it would seem that at present such instruments are too delicate, and the electric currents utilised too small, for them to be employed in portable illumination photometers for practical work. It should not be assumed, however, that we have reached finality in this respect. The work already accomplished has at least enabled us to appreciate the difficulties to be overcome, and it may be that in the future the hope of a direct-reading physical photometer will yet be realised. Seeing that progress in illuminating engineering is so dependent on convenient and accurate methods of measurement the study of these problems is extremely important, and we hope that friends in this country and abroad will continue their researches which should bear good fruit in time to come.

L. GASTER.

TRANSACTIONS

OF

The Illuminating Engineering Society.

(Founded in London, 1909.)

The Illuminating Engineering Society is not, as a body, responsible for the opinions expressed by individual authors or speakers.

SOME FUTURE POSSIBILITIES IN THE DESIGN OF INSTRUMENTS FOR MEASURING ILLUMINATION.

Proceedings at a meeting of the Society held at the House of the Royal Society of Arts, London, at 8 p.m., on Tuesday, February 22nd, 1916.

A Meeting of the Society took place as stated above, on Tuesday, February 22nd, Mr. F. W. GOODENOUGH being in the Chair.

The Minutes of the last meeting having been taken as read the names of the last applicants for membership at the last meeting* were read out again, and these gentlemen were formally declared members of the Society.

The Chairman then called upon Mr. Dow to open the discussion by presenting a series of contributions received in writing from various members of the Society. These included Mr. A. P. TROTTER, Mr. HAYDN T. HARRISON, Mr. P. J. WALDRAM (London), Dr. E. W. MARCHANT (Liverpool), Prof. C. FERY (Paris), Dr. H. E. IVES (Philadelphia). In presenting these communications, Mr. Dow explained that the authors had been invited to reply to the series of questions drafted to indicate the general scope of the discussion (see p. 80). Several of the contributions dealt specially with the applications of direct-reading instruments of the "physical" type.

An interesting discussion followed, in which Mr. A. CUNNINGTON (L. & S.W.R.), Mr. J. W. T. WALSH (National Physical Laboratory), Mr. J. M. TREZISE, Mr. R. WHIPPLE (Royal Meteorological Office), Mr. G. L. ADDENBROOKE, Mr. W. R. COOPER, Mr. L. GASTER, and THE CHAIRMAN took part.

In conclusion THE CHAIRMAN announced that the **next meeting** of the Society would take place at **5 p.m.** on **Tuesday, March 21st,** when there would be a discussion on "Some Aspects of the Design and Use of Glassware in relation to Natural and Artificial Illumination."

* *Illum. Eng.*, Feb. 1916, p. 41.

SOME FUTURE POSSIBILITIES IN THE DESIGN OF INSTRUMENTS FOR MEASURING ILLUMINATION

(With Special Reference to Photometers depending on Physical and Chemical Methods).

The following list of queries was prepared as an introduction to the discussion which took place at the last meeting of the Illuminating Engineering Society on February 22nd. It is not intended to be exhaustive but to serve as an indication of the general scope of the discussion.

(1) What possible methods can you suggest for making illumination photometers of the ordinary type (*i.e.*, those involving the use of a comparison source of light) more convenient for the use of the general public ?

(2) What are the prospects of making a satisfactory instrument depending on :—

(A) the principle of "extinction," *i.e.* diminishing the illumination to be measured until some small object just becomes invisible to the eye ?

(B) the observation of fine type—a minimum illumination being indicated by the fact of fine type becoming indistinguishable when viewed by the prevailing illumination at the point studied ?

(3) What are the prospects of making a satisfactory instrument depending on the following physical or chemical methods :—

(A) The use of selenium or other photo-electric cells.

(B) The use of thermopiles or other instruments for measuring radiation with or without a suitable solution or screen for absorbing the non-visible rays.

(C) The difference in expansion of two metallic elements, one polished so as to reflect a maximum of visible light, the other coated with an absorbent mat black material, but otherwise similar.

(D) The use of photographic methods such as the darkening of light-sensitive paper.

(4) What instances can be quoted of the above principles being used successfully in other fields of photometry, for example, in records of daylight, meterological observations, determining polar curves, observing fluctuations in the light given by various lamps, &c.

(5) Are you aware of any methods which could conveniently be employed in the design of instruments to indicate automatically when the illumination in an interior has fallen below a prescribed minimum, and an increase in the illumination is therefore necessary ?

SOME FUTURE POSSIBILITIES IN THE DESIGN OF INSTRUMENTS FOR MEASURING ILLUMINATION

(With Special Reference to Physical and Chemical Methods).

(Discussion at a meeting of the Illuminating Engineering Society, held at the House of the Royal Society of Arts, 18, John Street, Adelphi, London, W., at 8 p.m., on Tuesday, February 22nd, 1916.)

THE CHAIRMAN, in declaring the discussion open, mentioned that a number of contributions had been received from various members at home and abroad, in reply to the series of queries circulated previous to the meeting. He would call on Mr. Dow (Asst. Hon. Secretary) to present these communications.

Mr. J. S. DOW (Hon. Asst. Secretary), in presenting the written contributions to the discussion, remarked that a considerable amount of work had been done, both in Europe and in the United States, on instruments intended to serve as direct-reading photometers. As this work could be only briefly touched upon in the time available, members might be interested in the series of references given below based on information kindly

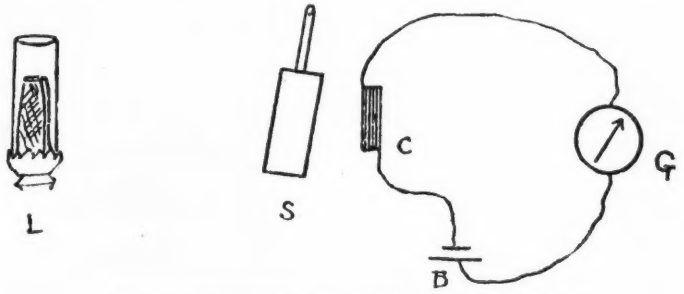


FIG. 1.—Arrangement of circuit for selenium cell (Ives).
L, Light source ; S, Shutter ; C, Selenium ; D, Battery ; G, Galvanometer.

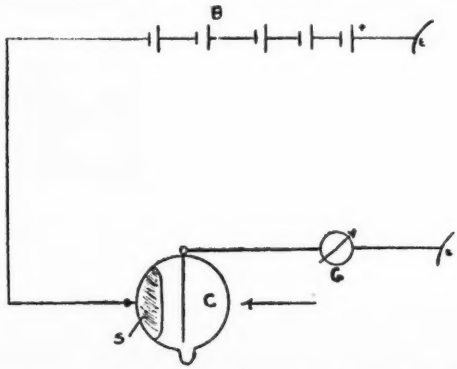


FIG. 1A.—Arrangement of Circuit for photo-electric cell (Ives).
B, Battery ; C, Cells ; G, Galvanometer ; E, Earth.

furnished by various members of the Society.* There had also been several past contributions in the ILLUMINATING ENGINEER, describing attempts to use photo-electric and other light-sensitive cells and also thermopiles for photometric work.†

As a preliminary to the contribution by Dr. Ives it might be of service to summarise briefly some of this earlier work. Attempts had been made to use both the selenium cell, the electrical resistance of which diminished under the action of light, and the photo-electric cell devised by Elster and Geitel. The essential arrangements for using such cells are shown in Figs. 1 and 1A (taken from a recent paper by Ives). In both cases the diminution in resistance, and hence the increased current furnishes an indication of the intensity of the light falling on the cell.

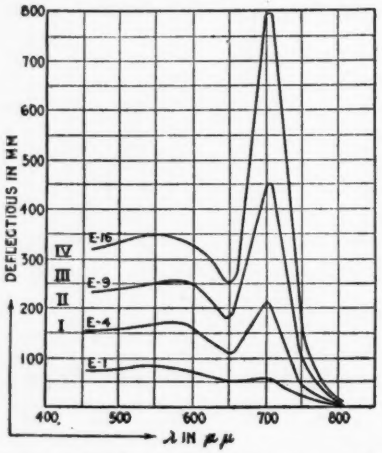


FIG. 2.—Showing the variation in relative sensitiveness throughout the spectrum of a selenium cell at different Illuminations. (E=1 to E=16.)

Such methods necessarily involve the use of a battery and galvanometer and this fact alone does not seem to favour their use by inexpert observers for making illumination measurements in practice. In addition there appear to be various difficulties arising from the physical peculiarities of such cells, such as the effect of inertia and other irregularities; and there is the further difficulty that the greatest effect is not produced by those rays in the spectrum to which the eye is most sensitive. In the case of the selenium Pfund has shown that the relative sensitiveness throughout the spectrum is utterly different in a weak light from what it is in a strong illumination—in this respect bearing a curious resemblance to the Purkinje effect in the case of the human eye. This is shown in the accompanying illustration.

In Fig. 3 the comparative sensitiveness throughout the spectrum of various photographic materials is illustrated. Obviously the selection of a material having a sensitiveness identical with that of the eye would present difficulties. Moreover, photography, although having certain applications, is in general a tedious operation compared with the use of a good

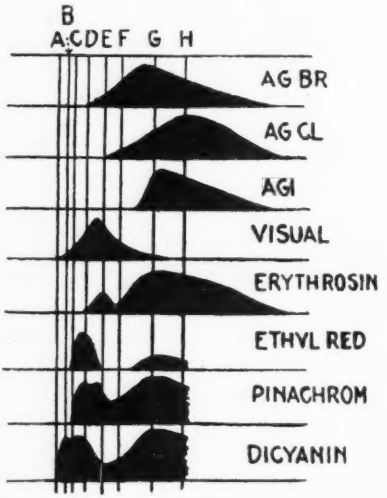


FIG. 3.—Showing differing sensitiveness throughout the spectrum of various photographic materials (Ives).

* Physical Photometry, by H. E. Ives (paper read before the Illuminating Engineering Society, U.S.A., November 7th, 1914); The Establishment of Photometry on a Physical Basis, by H. E. Ives (*Jour. of The Franklin Institute*, October, 1915; A Precision Artificial Eye, by H. E. Ives (*Phys. Rev.*, November, 1915); The Physical Photometer in Theory and Practice, by W. W. Coblentz (*Jour. Franklin Inst.*, February, 1916), &c.

† See "Objective Photometry," by W. Voege (*Illum. Eng.*, Vol. VII., 1914, p. 295; also Vol. I., 1908, p. 239, Vol. II., 1909, p. 10.)

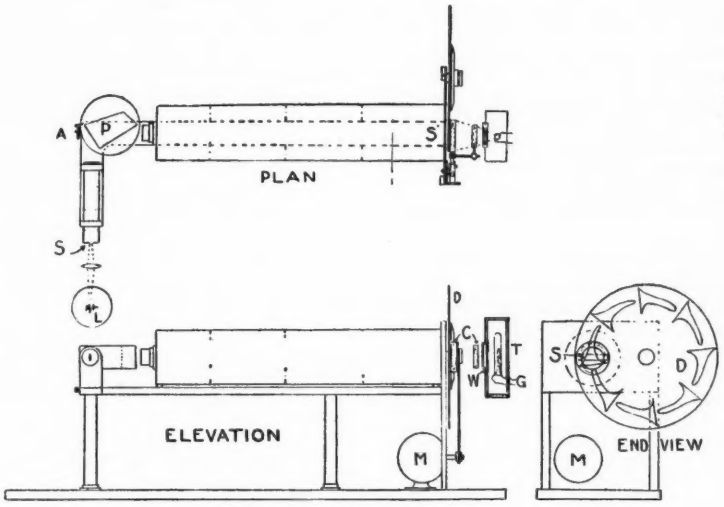
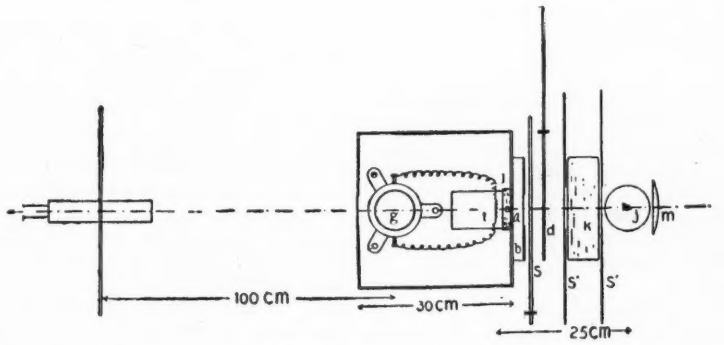


Diagram of precision artificial eye.

L. Light source.
S Slit
P Prism.
A. Adjusting screw
S' Point of formation of spectrum.
c Condensing lenses
T. Thermopile.
D. Spectrum template.
G. Galvanometer leads.

FIG. 5.—Instrument devised to give the effect of "Artificial Eye" (Ives).
(Using prismatic method.)



Physical photometer

t. Thermopile.
g. Galvanometer
l. Luminosity curve solution.
s. Shutter.
d. Sector disk.
s' Screens.
k. Water tank.
j. Light source.
m. Concave mirror.

FIG. 6.—Physical photometer (using cell of special solution).

illumination photometer. A special instance of the utility of photography is furnished by some experiments by Ives on obtaining polar distribution curves; photography has also the advantage of integrating with regard to time, and has therefore a special application for purely relative measurements of sources which fluctuate very rapidly over a short interval of time. (Tests on the "star-shells" used in military operations might furnish a case in point.)

Passing on to the use of thermopiles special reference may again be made to a paper by Ives in which the creation of an instrument to serve as an "artificial eye" is discussed. Fig. 4, taken from

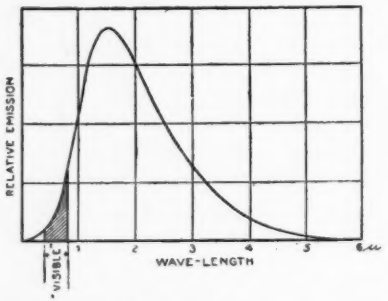


FIG. 4.—Showing that the visible rays form a relatively small proportion of the radiation from an incandescent solid.

this source, shows at a glance the difficulty of the problem. By special absorbing methods we have to obliterate the great mass of the radiant energy, leaving only the small shaded area representing luminous radiation. The amount of energy left is then very small, and highly sensitive instruments are needed to measure it.

Two methods of accomplishing this result are described by Ives and illustrated in the Figs. 5 and 6. In one case a cell of special coloured solution is used. This has the function of not only stopping the non-luminous energy but of diminishing the intensity of each wave-length throughout the visible area in such proportions as to render the effect identical with the sensation of the eye. (This method is also used in an instrument devised by Prof. Féry, see p. 88.)

In the other case the same result is accomplished by forming the spectrum of the light to be tested, diminishing the intensity at each point in the requisite proportion by means of a special sector-screen, and then integrating the spectrum and focusing the resultant light on a thermopile.

All this work is highly interesting and such instruments appear to have distinct value for laboratory work. But at present they do not appear to be capable of application in the form of a portable illumination photometer for every day use.

Mr. Dow then proceeded to present the communications of various absent members, as follows:—

A. P. TROTTER (*communicated*):—

(1) I do not think that "*the general public*" should be encouraged to amuse themselves with illumination photometers. Some experience is necessary and intelligent precautions must be taken to secure useful results.

Instruments of the lumeter and the luxometer type, having wide ranges of adjustment in addition to dark glasses, are bound to supersede the older instruments.

2. Physiological difficulties render all methods of "extinction" and "minimum visibile" misleading.

3. The differential bolometer depending on the resistance of a fine wire seems to be the best method depending on direct physical measurement: but it entails the use of expensive apparatus.

LIEUT. HAYDN T. HARRISON, R.N. (*communicated*):—(1) In my opinion it is essential that photometers for the general public should not embody the use of an eye piece, as few people can accustom themselves to work with one eye as accurately as they can when taking a general view of a screen with both eyes.

(2) (A) Satisfactory instruments can be made embodying the principle of extinction, but in order to get such extinction the colour difficulty should be carefully considered, and a standard light of similar spectrum used, otherwise the flicker principle is the more accurate when

the operator is not an expert photometrist.

(B) I do not consider any light measurements by means of type can be of much value, as it is more a test of eyesight than illumination.

(3) (A) I have had considerable experience with selenium, but find that the greatest care has to be exercised in the preparation and maintenance of the selenium cell; there is, moreover, a time lag which is often a serious disadvantage.

(B) The use of thermopiles or other instruments for measuring heat with screens for absorbing heat rays, strikes me as being novel, and I cannot imagine that a true luminous value could be measured by this means.

(C)————

(D) The use of photographic methods to indicate distribution of light will always be of value, but as an indication of intensity they are generally misleading owing to the emphasis laid on the violet or actinic end of the spectrum. As is well known, photo-productions can be made by invisible rays, whereas I always look upon light as the usable part of the spectrum.

(4) I have seen many photographic records indicating the fluctuations in arc lamps, and also light absorption by the deposit on the bulbs of incandescent lamps, but these of course were purely comparative, and could not be defined in terms.

(5) Not at the moment.

Mr. P. J. WALDRAM (*communicated*):—With reference to questions 3D and 4, I have been impressed by the remarkable coincidence between the measurements of daylight given by sensitised paper, exposure meters, &c., and direct measurement on a photometer by different observers. It would appear that the decided irregularities of actinic action are very possibly immaterial.

Work of a very different and more urgent nature has so far rendered impossible any experimental investigation by me; but I venture to anticipate with some confidence that sensitised paper photometers may some day be found to be sufficiently free from serious error to enable it to be applied to many practical every-day problems.

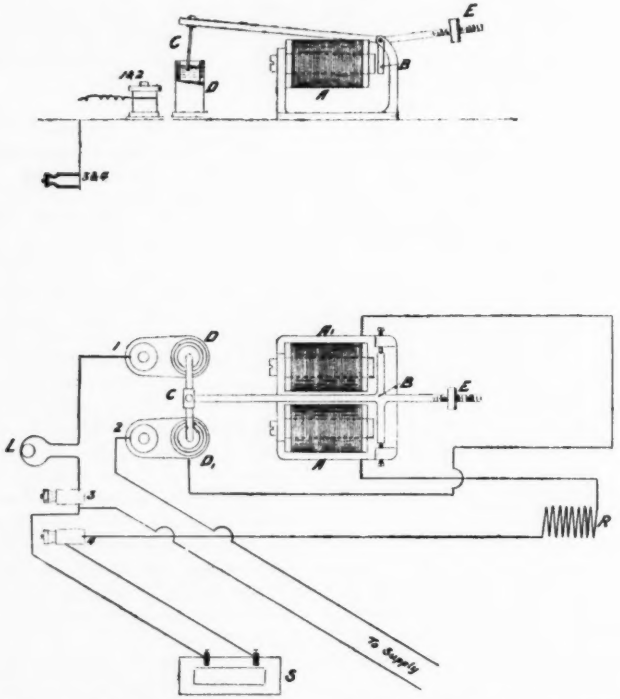
I may also recall the striking resemblance which was noted by the Meteorological Office between the curve of lumeter measurements of daylight on a certain day, as given in my paper in 1914, and the daily curve recorded by them of the radiant energy from the sky. This is another problem which awaits experimental proof.

PROF. E. W. MARCHANT (*communicated*):—The forms of illumination meter that I have used are the "Trotter" Illumination Meter and that made by Messrs. Beck, called the Holophane Lumeter. Both of these are quite convenient and simple. The chief practical difficulty with them is the keeping of the battery in good order; when, as often happens, they are not used for comparatively long periods, it is always necessary to use some form of voltmeter in connection with them, and I would suggest that this might be fitted to the instrument together with some correction tables by which the readings of the instrument may be corrected for variations in lamp voltage. It might be possible to devise some mechanical device whereby the readings were automatically corrected for variations in battery pressure.

An instrument depending for its reading on extinction of vision seems to me to have very small prospect of accuracy. The acuteness of vision to light depends on the opening of the pupil, and on the condition of the retina, and this varies with the immediate previous history of the eye. A photometer of a simple pattern for photographic purposes has been suggested in which this fact was made use of. I have no detailed information as to its construction, but the principle of its action was that an image of the pupil was produced by a semi-reflecting glass, and on this mirror, the diameter of the image of the pupil could be read off on a scale. This can only have been a rough and ready instrument, but for many purposes it might prove of value.

I had the opportunity of seeing an instrument some years ago, designed by Mr. Turner, the electrical engineer to the Hoylake District Council, which depended for its working on a selenium cell.

Mr. Turner has kindly contributed a detailed account of his apparatus. Its object was to switch on a street lamp when the illumination fell below a certain limit determined by the resistance of the selenium cell. Such a piece of apparatus I hope, by now, is being manufactured in England. Even with lights of different colours I have found that, with practice, it gives excellent results, far better than I have been able to obtain with Flicker photometers.



SKETCH OF MR. C. J. TURNER'S SELENIUM APPARATUS FOR CONTROLLING THE LIGHTING SYSTEM.

The selenium cell, S, is inserted in circuit with two electromagnets, A, A1. The lighting circuit contains the mercury cups, D, D1, which are connected by the forked contact piece, C, attached to lever-bar controlled by electromagnets. B is the pivoted armature attracted by the magnets. E is an adjustable balance weight for altering moment of contact, R a resistance placed in circuit with magnet coils (in this case about 14,500 ohms), L the lamps controlled by action of selenium.

Selenium has the property of diminishing in resistance when exposed to light; the variation in this case being from 3,000 ohms. in light to 150,000 ohms in darkness.

In full daylight, therefore, a relatively strong current flows round the magnets, which draw up the armature breaking the circuit at the mercury cups, D, D1. The lamps are thus extinguished.

When darkness comes on the resistance of the selenium increases and the current energising the magnets is diminished until, eventually, the armature is released and current is established at the mercury cups lighting the lamps.

The exact point of switching on can be regulated by the balance weight, E.

has great possibilities, and might easily be applied in schools as an indicator as to when the lights should be switched on.

For accurate comparison of illuminations I have found nothing better than the Lummer Brodhun Photometer, which

Dr. H. E. IVES (*communicated*):—I was interested to learn of the forthcoming discussion of physical photometry in the London Illuminating Engineering Society. It hardly seems necessary to repeat the opinions and experiences already

published in my recent and somewhat exhaustive papers on the subject. It may, however, be of interest to mention some more recent work which has not as yet appeared in print, or on which we are working or merely contemplating work.

In regard to the photo-electric cell, it may be recalled that a most serious objection to its use is the lack of direct or uniform proportionality between the illumination and the current. This is a subject on which we have been working for some time, and we have rather recently established the conditions under which this important relationship is strictly rectilinear. As a result of this work a new design of photo-electric cell has been worked out, in which the current does not vary in unexpected ways from the illumination. With this improvement in the photo-electric cell it is a wonderfully sensitive instrument for use where no questions arise as to colour differences. There still of course remains the disadvantage that apparently no two photo-electric cells have the same wave-length sensibility curve. This is one of the problems on which we are doing some work at the present time. Should it prove possible to make cells of uniform wave-length sensibility, so that a luminosity curve sensibility could be produced by the proper absorbing media, then the photo-electric cell would be probably the most sensitive and convenient of all forms of physical photometers.

In regard to the thermopile physical photometer, which is described in a number of recent papers, this instrument is working admirably in practice. Its only drawback of course is that its sensibility is so low that it can only be looked upon as a laboratory instrument. Since, however, it is being rather generally agreed upon now that all photometric work involving colour differences should be done in a standardising laboratory, this objection is not at all serious.

In connection with this question of sensibility I may say that I am at present very much interested in the possibility of increasing the effective sensibility of all kinds of radiation measuring instruments by some sort of current amplifier along the lines of those which have been recently developed for wireless telegraphy and telephony. There is, however, nothing definite to report on this beyond the fact that the possibility is an attractive one and is receiving attention.

DR. W. COBLENTZ (*communicated*) :—In connection with the question of the "Possibilities in the Design of Instruments for Measuring Illumination," physical methods demand a careful unbiased investigation. A measurement made with a physical instrument is a definite thing that can be repeated at any time with the expectation of obtaining the same value as was observed in the beginning. The physical photometer is not subject to such vagaries as are experienced in visual photometry. The instrument, as we know it, is not so sensitive as visual photometry. It requires fairly high intensities but for certain classes of work is not detrimental.

A promising form of physical photometer consists of a quick acting thermopile in front of which is placed a screen which is opaque to all the infra-red and ultra-violet radiations, and which transmits the visible radiations in proportion to "visibility of radiation curve" of the average normal eye. The thermopile or bolometer is used in connection with a sensitive d'Arsonnal galvanometer, or (when radiometering low intensities) with an iron-clad Thomson galvanometer. Iron-clad Thomson galvanometers are easily and cheaply made by imbedding the coils in blocks of Swedish iron, which are surrounded by short pieces of soft iron gas pipe. Such a galvanometer is easily shielded magnetically, so that the objections raised by experimenters, who are familiar with unshielded Thomson galvanometers, are overcome.

A physical photometer of this type, unlike the eye, functions independently of the frequency (colour) and the intensity of the stimulus. During the past summer the writer made a short test of the performance of this type of physical photometer as compared with a visual (equality of brightness) photometer, in which the test object was a standard incandescent lamp, which had been photometered by various observers in various laboratories. The ratios of the luminous intensities of a standardised tungsten lamp, determined

photometrically, and radiometrically with the physical photometer, were found in agreement within 0·2 per cent. This is a very close agreement, considering the fact that the radiometric measurements were obtained in the course of a few hours, while the photometric measurements represented several weeks of work. This close agreement is not accidental, however, for the physical photometer is not subject to variations such as are common to the eye, and it must give the same result from day to day.

Subsidiary questions remain for further investigation. The example the transmission of the solution used in front of the thermopile seemed to change slightly after several exposures to the lamp, and it remains to be determined whether this was due to a photochemical reaction which is reversible. For further data the reader is referred to the Journal of the Franklin Institute, September, 1915, and February, 1916; also *The Physical Review*, November, 1915.

PROFESSOR C. FERY (*communicated*) :—I have been prevented from following up the study of a new form of photometer by very urgent work given me by the Commission of Inventions. I must therefore ask you to excuse me for not having given you yet the details of this new apparatus. The instrument is described in the *Bulletin de la Société Internationale des Electricians* (Series 2, Vol. IX. No. 90).

The only methods practically employed for measuring light depend on the impressions of the eye, as received by observation of two adjacent illuminated surfaces in a photometer. This method necessarily involves the employment of a standard of light, and, being subject to a physiological impression, there is always the danger that the results of measurement will depend on the visual peculiarities of the observer.

I have made observations on a number of my pupils, and have found that considerable personal differences exist. No doubt Daltonism would play a part in cases where the colours of light yielded by standard and source tested are not the same. The use of a monochromatic (Crova) screen has not appreciably affected the mean, but has caused to disappear the large differences previously encountered in the readings of different observers.

It would therefore be very desirable to adopt a "direct-reading photometer" or an "artificial eye," to use the expression adopted by Ives in his experiments.

Among the forms of direct-reading instruments are those depending on :—

(1) The use of a selenium cell.

(2) The use of a photo-electric cell.

(3) The use of photographic preparations.

(4) The use of apparatus for measuring total energy radiated by the incandescent body.

No. 1 has the inconvenience (among others) that the indication is not proportional to the luminous sensation, the maximum sensitiveness of which for the normal eye is located at 0·54μ. Moreover, the cells are not constant and their sensitiveness diminishes with time.

No. 2 is open to the same objections.

No. 3 yields with silver salts a maximum sensitiveness near 0·34μ; moreover, it is necessary to estimate the light-effect by measuring the opacity of the image on the plate, and this is by no means proportional to the illumination. The use of ortho-chromatic and other colour-sensitive plates removes the first objection but not the second.

No. 4 appears the best worthy of examination. The response of a bolometer depends on the temperature of the incandescent source, being related by the Law of Wien :—$\lambda_m\theta$ = constant. The method has therefore a tendency to favour sources of low temperature, just the opposite to the tendency with photographic methods.

Nevertheless it is possible to get over this difficulty by the use of suitable screens. In 1908 I employed with success a radio-micrometer combined with a screen composed of a solution of copper acetate in order to provide a direct-reading photometer, giving the same sensitiveness throughout the spectrum as the normal eye. More recently I have used such cells with a thermopile. The use of my solution gives a system with a maximum sensitiveness near 0·54μ, identical with that of the retina; to achieve

this result a thickness of 4 cms. of copper acetate solution (17 grms. per litre) is used.

One could also stop the invisible radiation by using a prismatic arrangement instead of screens. For this purpose one must form a spectrum image of the source to be tested, placing in front of it a screen cut in such a way that the ordinate at each point is proportional t o the luminous impression received by the retina. The radiation is then integrated and received on the instrument for measuring the radiation. This arrangement is theoretically very successful, but in practice may be replaced by a cell filled with suitable absorbing liquid. One can make use of a bolometer of the type described by Dr. Drysdale for determining the mechanical equivalent of light, a galvanometer of the type worked out by Ives, or a Boys' radio-micrometer modified in the manner described in my researches. I have likewise employed an invar-brass couple similar to that used in the spiral pyrometer constructed by the Cambridge Scientific Instrument Co.

The bi-metallic strip was blackened on the side facing the radiation, and carried a quartz fibre, the movement of which could be measured with a microscope. By this simple procedure I think one could arrive at a sensitiveness sufficient for practical purposes.

The war has interfered with these experiments. I am convinced, however, that the photometer of the future will be of a type independent of the personal peculiarities of the observer, for the invariable tendency in physical matters is to devise methods of measurement which are independent of physiological processes. Chronography and astronomy have replaced the ancient measurements dependent on the eye and the ear. Similarly I believe that by a calorific measurement one can best evaluate the intensity of radiant energy.

Mr. ARTHUR CUNNINGTON (London and South-Western Railway Co.), dealing with the first question said that although Mr. Trotter did not advise that photometers should be made for the use of the general public, nevertheless something might be done in order to simplify readings. In some quarters there was a tendency to exaggerate the difficulty in making illumination measurements, which he thought was due to being unaccustomed to this sort of work. Some people even could not read a gas meter correctly, but it was simply because they were not used to doing it, and he was of the opinion that with a little practice it would be a simple matter, with a suitable instrument, for any ordinary person to take photometric readings. We had already progressed very considerably from the days of the purely laboratory photometer, and there were various directions in which simplification could be carried still further.

When he first began taking measurements on a fairly extensive scale with the Lumeter, he found one thing required was something to hold the illumination card in a horizontal position, especially when a large number of measurements were being taken over an area, in a horizontal plane at some fixed height above the ground. He was aware that a tripod stand was supplied for this purpose, but moving and resetting this for several dozen successive readings was a tedious process, and one could not always afford the luxury of an assistant. Therefore, in order to make the instrument self-contained, he had designed a form of adjustable holder which could be attached at one end to the lumeter by a spring clip, and at the other end carried the white screen. This, he had found, saved a great deal of time.

He had often noticed that a rough test of the uniformity of illumination in a given area could be made by setting the lumeter at some average figure and,while keeping this fixed illumination in view, moving from place to place and noting where the illumination differed widely from the average.

This principle of setting the Lumeter at a given point suggested the use of an instrument with several of such fixed values, in which no scale would be required, but in which the illumination would be roughly gauged by observing which of the values most nearly balanced with the existing illumination. He exhibited a model of an instrument of this type (for the making of which he was indebted to his father), and showed a slide

illustrating it (Fig. 1). The top surface of the box consists of a white screen with a number of spots upon it illuminated from behind. Various degrees of illumination are obtained by varying the size

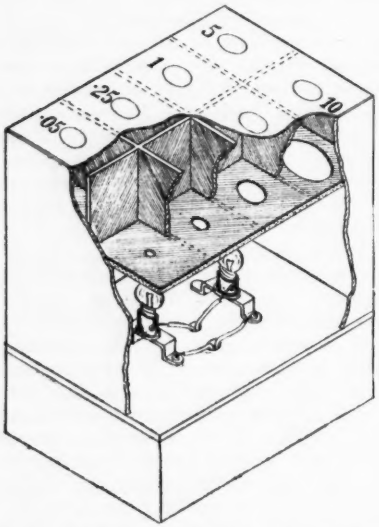


FIG. 1.—"Box Photometer" (Mr. A.Cunnington).

of the holes in the middle diaphragm, and thus altering the area of the light source available. The light from the lamps in the lower part of the box shines through opal glass, or other translucent material to give uniformity of illumination, and this lower part is whitened throughout in order to secure the maximum diffusion.

The battery can be fixed under the box or at one side of it. The chief points in a scheme of this sort are :—

(1) That no manipulation is required.

(2) That it shows at a glance the general character of the illumination, and changes can be readily detected.

(3) That, as the instrument has not to be carried at eye level, the battery can be contained within it.

This idea might be developed still further and made in a very compact form for a single standard, by using an ordinary torch lamp with accumulator, and fixing in front of it a screen illuminated to exactly some prescribed value. Such a pocket standard might be useful for rough testing in factories in order to be sure that a minimum illumination was obtained.

In all these arrangements some form of battery was necessary, and that was certainly a drawback, although he thought the difficulties of dealing with a battery were often much exaggerated. It was important to have a voltmeter available to check the voltage of the cell, and to know when it was failing. He was interested in Prof. Marchant's suggestion as to using correction tables, as he had been in the habit of making a percentage correction in readings when the voltage of the cell varied from the normal. It might be convenient to scale the voltmeter not in "volts" but in "percentage error," with a centre zero at the normal voltage of the cell. He did not recommend that such an instrument should be permanently attached to the photometer, but should be capable of being clipped across the terminals of the cell whenever required, and would then indicate directly the correction to be made, if any.

At the same time it should be remembered that a battery of reasonable capacity remained steady for a long time, and he had often used batteries for several weeks on end, taking readings constantly without any trouble. A rough indication of falling voltage could be obtained at any time by simply holding on the switch of the Lumeter and observing whether the illumination inside remained constant or gradually diminished. He strongly deprecated, for practical illumination measurements, the carrying about of what was equivalent to a complete photometric laboratory. It was said to make one "independent of a laboratory." That might be true, but only at the cost of carrying the laboratory about with you. He thought all checking against standards should be done before going out to test.

With regard to the second question, Mr. Trotter had already expressed the opinion that the physiological difficulties were practically insuperable. He had, however, made a few rough experiments in the direction of an "extinction" photometer in the hope that even if only very approximate results could be obtained, there might be some field for an instrument of this class, having the great

advantage of dispensing with battery and comparison lamp.

He exhibited a rough model of the arrangement as outlined in Fig. 2. The idea was to look through a transparent diaphragm on which was marked some fine lines or small type, at a background which was lighted by the illumination it was desired to measure. This background was graded in shade from very light to very dark. Then if the illumination were high a very dark background

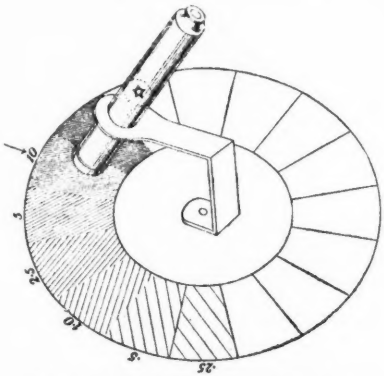


FIG. 2.—Suggested instrument based on "contrast" (Mr. A. Cunnington).

could be placed behind the diaphragm before the fine lines or type became invisible, whereas with a low illumination, they would be indistinguishable against a much lighter background. The variations in the background would thus indicate the degree of illumination. He regretted that up to the present he had not got any reliable results, so much depending on quality and condition of eyesight.

Mr. J. M. TREZISE:—

I was hoping to be able to show this evening some experimental photometric apparatus with which I was working some time ago, but I have not been able to get very much ready for the meeting. I will, therefore, confine myself chiefly to the description of a special form of photometer screen.

I was recently engaged in the design of a convenient form of portable photometer making use of a lens to view the illuminated surfaces to be compared so as to permit of the instrument being of small dimensions. I had difficulty in finding a screen which would stand much magnification without the surface appearing granular and the edge either lighter or darker than the rest of the field. I noticed, however, when making experiments with opal glass, that the broken ends of what is known as flashed opal glass (*i.e.*, clear glass with a thin opal surface on one side) presented a remarkably uniform brilliancy when viewed at a suitable angle. This evenness of brilliancy is not disturbed by the irregularity of the broken end of the glass when it is cut by being scratched on the opal side by a diamond or preferably a cutting wheel and broken. In the ordinary way this uniformity extends up to the edge of the surface of the broken end so that, when used as a photometer screen, it presents a clean sharp edge giving a fine dividing line between the two illuminated surfaces; if the lights are of the same colour this edge disappears altogether when a balance is obtained.

I have here a piece of flashed opal glass which is very thick so that you may see the edge without magnification, and if I place it so that you are looking at the broken end at an angle of about 40° from the normal you will see the effect I have described.

The arrangement is shown in Fig. 1.

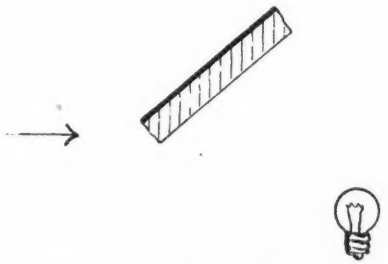


FIG. 1.—Inclined glass edge screen (Mr. J. M. Trezise).

By placing a black screen with a circular hole in it so as to hide all but a semi-circular portion of the end of the glass as in Fig 2 we arrive at the arrangements used for the photometer in measuring surface brightness, a view of

the test plate being obtained through the semi-circular dark hole at the top in instruments.

In the model, Fig. 3, which is being passed round for you to see, the glass is thinner and a lens is provided to give a field which corresponds to a circle 4 inches diameter at a distance of 2 ft.—which is sufficiently large for ordinary work.

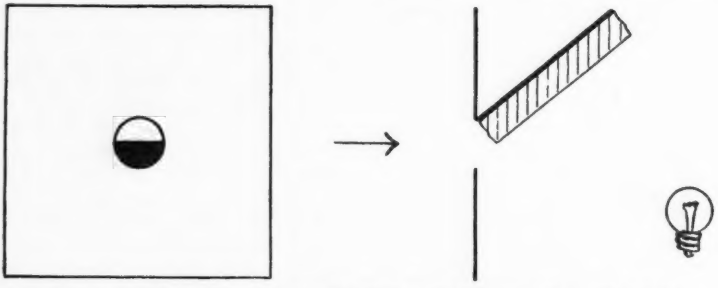


FIG. 2.—Inclined glass edge as embodied in photometer and resulting field of view (Mr. J. M. Trezise).

In Figs. 1 and 2 the light is placed on the side remote from the opal surface and the brilliancy seen is that of the side of the opal surface next the light. In this case ordinary clear glass painted white at the back may be used. In Fig. 3 the light is on the opal side of the glass and the brilliancy is less as the light is filtered through the layer of opal glass.

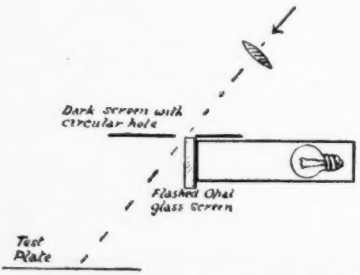


FIG. 3.—Small illumination photometer using inclined glass edge screen (Mr. J. M. Trezise).

This form of screen lends itself very nicely to photometry of small dimensions; indeed, if desired, it is possible to make quite a satisfactory instrument very small indeed. I have used one which reads from 1 foot-candle to 100 ft.-candle fixed to the objective of a microscope and which is contained in a tube $\frac{3}{8}$ inch diameter by $1\frac{1}{2}$ inch long. A somewhat similar instrument is shown in Fig. 4, a model of which is shown on the table. The variation in the brilliancy of the screen (*a*) as viewed through the lens (*b*) is effected by rotating, half a revolution, the tube (*c*) containing a glow lamp of about $\frac{1}{20}$ candlepower, and an opal glass window (*d*). When this window is opposite the piece of flashed opal glass (*a*) the brilliancy corresponds to 1 ft.-candle. When it is in the position most remote from (*a*), *i.e.*, when the tube has been turned through half a revolution, the brilliancy is 0·1 ft.-candle. By turning the cap (*e*) so as to bring the grey glass (*f*) in the line of vision the brilliancy of the test plate is reduced to $\frac{1}{10}$ of its value, and the readings on the scale increased tenfold. Thus the instrument as constructed with one piece of absorbing glass reads from 0·1 to 10 ft.-candle.

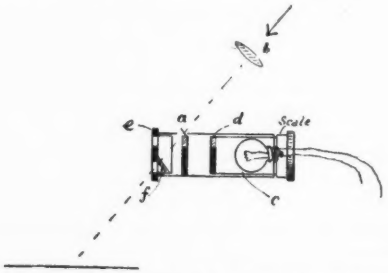


FIG. 4.—Showing use of two apertures whose relative position can be altered to vary illumination (Mr. J. M. Trezise).

The determining factor in the size of this model was the diameter of the glow lamp. I should have used a smaller tube if I could have got the smallest lamp I had into it. The lamp also gave far too much light and for instruments of this kind where it is possible to bring the lamp very close to the screen this is generally the case.

In this instance I wanted a maximum brilliancy of the screen to match 1 ft.-candle of illumination but the lamp, which is a 2·5v. lamp run at 2v. and gives about ·5 candlepower, gave 20 ft.-candles on the screen, *i.e.*, 20 times more light than is necessary.

The possibility of using a very small lamp for a portable photometer ought to reduce considerably battery troubles.

In the instrument of which Fig. 5 is a diagrammatic representation two screens (*a*) and (*b*) are used. The tube (*c*) containing a ·5 candlepower lamp is provided with an opal glass window of about $\frac{1}{8}$ inch diameter which when it is brought close to the screen gives a brilliancy corresponding to 60 ft.-candles,

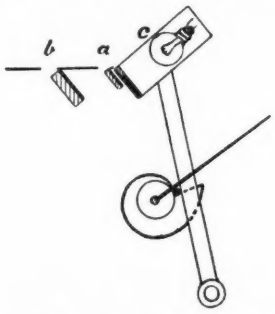


FIG. 5.—Use of two inclined glass edge screens (Mr. J. M. Trezise).

and when it is moved from the screen to a distance of about 1 inch by means of the snail the brilliancy is reduced to 0·6 ft.-candles the observation being made through a lens over the aperture at (*a*). For lower readings the lens is moved to a position over screen (*b*) which is illuminated by the light passing through screen (*a*) and is placed at such a distance from (*a*) as to attain a maximum brilliancy corresponding to 0·6 ft.-candle, and this may be reduced by the movement of the lamp to 0·005 ft.-candle.

By a movement of the lamp of about 1 inch therefore the range of the instrument is from 60 to 0·005 ft.-candle and the introduction of a grey glass to reduce the brilliancy of the test plate increases the maximum to 6,000 ft.-candles or to 60,000 ft.-candles by the use of a coloured glass for daylight measurements.

I may say that in arranging the absorption glasses the necessity for exact adjustment of the glass or the use of wedges has been avoided by selecting glass of suitable colour with an absorption somewhat less than that required, the exact value being obtained by inclining the glass from the normal to the pencil of light until the required absorption is given.

By means of an opal glass screen in the line of vision the instrument may be used for candlepower measurements, and if the light to be measured is a predetermined distance from the instrument direct readings are obtained. If, for instance, the light is 7 feet away the candlepower will be the scale readings multiplied by 100. This arrangement is convenient for taking polar curves of lamps or shades.

The snail is designed to give a log scale which I have found to be the most convenient for an instrument of this kind.

Two screens may be arranged as in Fig. 6 for use as a photometer head for bench work.

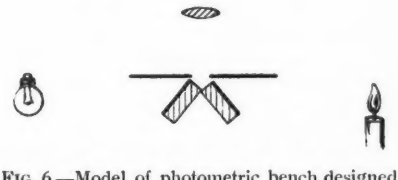


FIG. 6.—Model of photometric bench designed to show principle of instrument (Mr. J. M. Trezise).

The arrangement, when used on an ordinary bench seems to be very sensitive, but I should explain that the model makes it appear more sensitive than it really is as the lights are closer to the screens than they would be in actual practice.

The models on the table may be inspected at the close of the meeting.

Mr. J. W. T. WALSH (National Physical Laboratory) said that before venturing to offer a few remarks on the third section of the headings set out for discussion, he would like to say that he had had no first hand experience whatever of physical photometry. Photometric work at the N.P.L. had always been by visual comparison and although, shortly before the outbreak of war, the question of a research into the possibilities of physical photometry was being discussed, the matter had necessarily been temporarily abandoned owing to the large amount of more pressing work now demanding all the attention and energy of the staff. Physical photometry, originally developed along practical lines in Germany, had during the last few years—he might also say months—made great strides in the United States where several workers had published—chiefly in the Physical Review—the results of their researches on this subject. The chief methods of physical photometry might be roughly classified in two main divisions, (*a*) those employing photo-electric phenomena, and (*b*) those depending on the measurement of radiation, and involving, usually, some form of thermopile and galvanometer. He might, perhaps, be forgiven for running quickly over the basic principles underlying the photo-electric cell. In 1888 Hallwachs* discovered that a negatively electrified body lost its charge when ultra-violet fell upon it. A year later Elster and Geitel† showed that electro-positive metals, like sodium, potassium, and rubidium exhibited the same effect when exposed to ordinary light. This phenomenon, however, only occurred with freshly formed metal surfaces, for if the plates were allowed to stand in air, their activity would rapidly diminish. Later it was discovered‡ that the sensitiveness of the metal surfaces could be much increased by placing them in a bulb containing hydrogen at low pressure and causing a glow discharge to pass between electrodes sealed in this bulb. Under this treatment the metal undergoes a modification of form in the course of which its surface becomes coloured and is found to be three or four times as sensitive as that of the pure metal. The hydrogen in the tube must be subsequently replaced by argon or helium, otherwise the sensitiveness would be found gradually to diminish as time went on. The figure

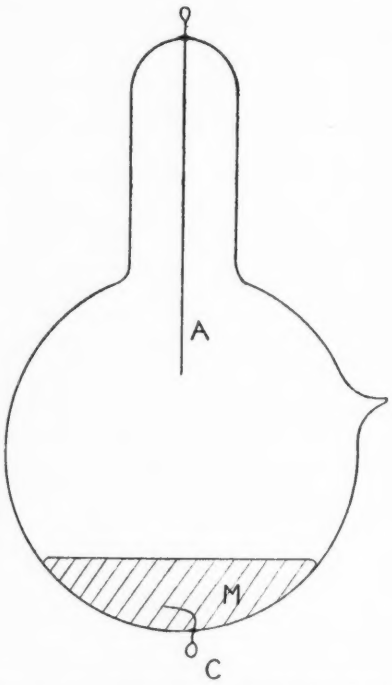


FIG. 1.—Usual form of Elster and Geitel photo-electric cell (Mr. J. W. T. Walsh).

showed, somewhat diagrammatically, the form generally taken by a sodium or potassium photo-electric cell. C is the cathode wire in contact with M the active metal, while A is a wire anode. The metal has undergone the preliminary treatment with hydrogen described above and the globe is filled with either argon or helium. On applying a potential of say 6 to 12 volts between A and C, and illuminating the surface of M, a current is found to flow through the cell. This current is exceedingly small, generally of the order of 3 by 10^{-10} amps, per foot-candle, but it has been found to be

* Hallwachs, *Ann. d. Physik*, 33, pp. 301—312, 1888.

† Elster and Geitel, *Ann. d. Physik*, 38, pp. 40, 497, 1889.

‡ Elster and Geitel, *Phys. Zeitschr.*, 11, pp. 257—262, 1910; 12, pp. 609—614, 1911.

accurately proportional to the degree of illumination of the metal surface over the extremely wide range of 0.01 to 620 foot-candles. Richtmyer, in America, had described an ingenious null-method of photometry by means of such photo electric cells.* His apparatus consisted of two similar cells arranged with two sources of potential after the manner of a Wheatstone Bridge as shown in the figure.

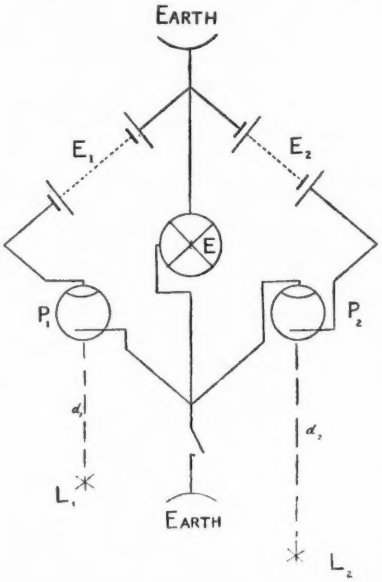


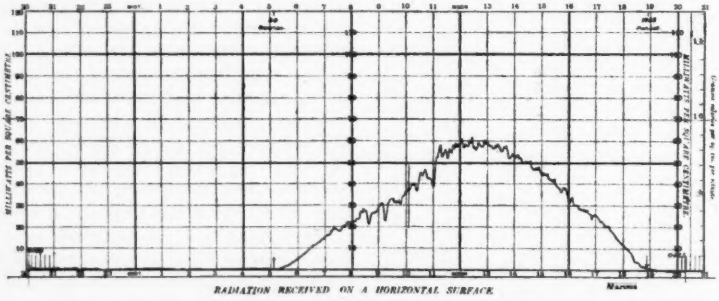
FIG. 2.—Connections for using photo-electric cells on Wheatstone Bridge principle (Mr. J. W. T. Walsh).

P_1 and P_2 are the two cells and e_1 and e_2 the two sources of potential the connected ends of which are of opposite polarity. The indicating instrument E is a sensitive electrometer. First, the values of e_1 and e_2 are adjusted by trial so that the dark currents through the cells (*i.e.* the currents passing when the cells are unilluminated) are balanced. The two sources of light to be compared are then placed so that each illuminates one cell, and their respective distances from the cells are adjusted until there is again no deflection on the electrometer. It has been found that the two cells obey the same law connecting current and illumination, so that once the constant of the apparatus has been determined it forms a ready means of comparing illuminations. In practice, differences of the order of 0.01 per cent. are said to be detectable, but it was to be presumed, he said, that an essential condition was that the light compared must be exactly of the same spectral distribution otherwise colour screens must be employed to render the sensitivity curves of the cells identical with that of the average eye. Such a screen had been devised by Dr. Voege and his work was described in the ILLUMINATING ENGINEER for June, 1914. He thought it might be said without fear of contradiction that in the case of the photo-electric cell, at least, comparison of two sources of light was all that was in any way practicable at present, and though it would be a distinct advance to be able to supplant the human eye by some physical apparatus, yet it would be a still greater boon if some means could be found of actually measuring illumination without the necessity of constant reference to some standard of comparison. Advance along these lines appeared more promising, he thought, in the case of the second class of physical photometers to which he had made reference above, viz., those in which the radiation from a source was measured by some instrument working generally on the principle of the thermopile. Dr. Ives, from whom they had had a most interesting communication that evening, was one of the pioneers in this field of physical photometry, and he was very intereste d to hear of the experiments progress being made, and of the results indicated. Mr. Dow had already given a very complete account of the methods and apparatus employed and there was therefore nothing for him to add as regards that portion of the subject. If he might be allowed another minute or two, however, he would like to ask the opinion of those present on a form of neutral filter for photometric use, the design of which had occurred to him some few months ago but which he had not had the opportunity of testing fully. It consisted of a piece of clear glass coated with

* F. K. Richtmyer, *Phys. Rev.*, 6, pp. 66—68. July, 1915.

an opaque dead black varnish. Fine lines were then scratched through the varnish thus baring the glass and presenting a transmitting area which might bear any desired ratio to the opaque, non-transmitting area. If these lines were carefully ruled the transmission coefficient would be even all over, and a very rough specimen he constructed hastily the other day gave a surprisingly even field when used in front of a Lummer-Brodhun photometer head. The lines were about $\frac{3}{4}$ mm. apart and the transmission coefficient came out to be in that case about 7 per cent. Such a device had very probably been employed before but as he had never seen an account of it, he thought it might be useful to mention it, because one of the problems which had given them considerable difficulty in illumination photometry at the N.P.L. had been the practical impossibility of obtaining a neutral filter glass. A similar device which had proved useful just lately in the reduction of very green illuminations was the use of successive thicknesses of black tulle. Each thickness was found to produce a reduction of approximately 9.3 per cent. and at 14 thicknesses the reduction was still sensibly the same, the transmission coefficient of this number of thicknesses being about 25 per cent. He should be very glad to know if such a form of filter had been used before. If so, no doubt someone present would have either seen an account of it or would have had first hand experience of its possibilities and limitations.

Mr. F. J. W. WHIPPLE, speaking upon Question 4, said that the instrument used more than any other for recording radiation in the meteorological service was the Campbell-Stokes sunshine recorder in which the light coming through a spherical lens browned a strip of blue cardboard and a record of the duration of sunshine was obtained. Of the instruments for measuring the direct intensity of the sunshine, the best known was the Angstrom apparatus in which there were two metallic strips, one of which was heated by sunshine and the other by a current passing through it. By means of a thermo-junction on the back any difference between the temperatures of these two strips was shown and the current was adjusted until the difference vanishes. This instrument had been given official sanction in more than one International Conference but it took a considerable time for each observation and was by no means portable. The portable apparatus which was most in favour for measuring the intensity of sunshine was Abbot's Silver Disc Pyrheliometer. Another instrument of a rather similar character was known as the Michelson Actinometer. In this there was a bi-metallic strip which was exposed to the illumination of the sun and then shut off from it. On the end of this bi-metallic strip was an aluminium arm carrying a quartz fibre, the movement of which was watched by means of a microscope and in this way the variation in the intensity of the sunshine could be measured with the utmost rapidity. It was practically a dead beat instrument. A steady reading could be obtained in 10 seconds which was remarkably quick for a purely mechanical device of this



Record of total radiation received during Saturday, August 29th, 1914, at the South Kensington Station (Mr. F. J. W. Whipple).

nature. An instrument which directly measured the heating effect of light from the sky as well as from the sun was the Callendar electrical recorder, and there should be no difficulty in making use of this instrument for practical illumination measurements. It could certainly be used for measuring the intensity of daylight illumination which he presumed came within the scope of the work of the Illuminating Engineering Society.

Mr. G. L. ADDENBROKE said that he had for some years carried out experiments on selenium as a dialectric.

The question of the effect of impurities was important. Twenty years ago he had made experiments on this point and had analysed the constitution of the impurities, amounting to about ½ per cent. These proved to consist partly of brass and partly of copper. The whole value of these cells lay in their preparation and, speaking generally, this must be regarded as an element of uncertainty. A great many people had spent time in preparing the cells in various ways, and found that their utility depended very much on this small impurity.

When it was remembered that a cell was frequently put on one side for long periods and then taken again into use, their conditions at the present stage did not appear very hopeful. The position seemed very similar to that which occurred in photography twenty-five years ago when many people were experimenting with the gelatine process. Many of these people were not chemists or scientific men, but by making a very large number of experiments, one out of the whole lot gave surprisingly good results, and this led to further progress.

He was much interested to hear of the work of Ives and others in the United States, and perhaps their work would eventually lead to a similar result.

Mr. W. R. COOPER said that the question referring to selenium appealed to him, but unfortunately it was not a very satisfactory substance to deal with. The sensitiveness of selenium did not correspond with that of the eye, for it was sensitive practically only to the orange part of the spectrum and consequently the effect produced by light varied with the wave-length. The sensitiveness also depended upon the heat treatment given to the selenium in preparing the resistance, the thickness of the selenium and the method of construction adopted. If selenium was used for photometric purposes it was necessary to calibrate the instrument, and it was quite impossible to compare sources of light differing in character; thus a source rich in red could not be compared with one deficient in red, except by means of special calibration. There were also other difficulties; the variation of resistance depended upon the length of exposure and complete recovery took a considerable time. Thus it was necessary to adopt a definite cycle in photometric work, the selenium being exposed for a short time and then allowed to recover for a certain time before another observation was taken. In looking over the literature on the subject he was struck with the fact that the amount of quantitative work carried out on the construction of selenium resistances was very little. Much more would have to be done in this direction before an idea could be obtained as to how a definite sensitiveness was obtained. Although there were objections to using selenium directly for photometric work it seemed to him that it might be used as a detector for comparing illuminations, and it would have the advantage of being free from fatigue which was troublesome to the eye. He could not agree with the opinion expressed by Mr. Addenbrooke that the action of selenium depended upon impurities. All the research for many years past was entirely against this view. With regard to the use of voltmeters on illumination photometers to check the constancy of the accumulators it should be remembered that a small voltmeter would not easily give a reading of one per cent. and that the variation of one per cent. in the voltage meant considerably more than one per cent. in the illumination.

Mr. L. GASTER (Hon. Secretary) expressed his appreciation of the interesting contributions to the discussion.

He thought the time was ripe for the invention of some simpler instruments for measuring illumination, which might permissibly be less accurate than the

illumination photometers already available, but which would enable managers of works to tell at a glance the order of illumination prevailing in their factory.

The possibilities of selenium had always interested him, and he recalled that Dr. Ruhmer of Berlin had shown him, years ago, selenium cells which he stated were perfectly pure. He believed that the manner in which such selenium was prepared was of considerable consequence and had a distinct influence on the distribution of sensitiveness throughout the spectrum. It was of interest to recall that about twelve years ago a portable photometer using selenium was contrived by Dr. Torda. In this case the effect of fatigue due to continuous exposure to the illuminant was obviated by an automatic shutter which covered the cell after it had been exposed for a few seconds. This shutter was operated by clockwork and made it impossible to use the cell, except after a suitable interval for recovery.

In the course of his visits to factories he had been informed by the manager of one large factory that he had contrived a selenium apparatus to indicate, by the ringing of a bell, when the illumination fell below a specified value. Mr. Turner's apparatus seemed intended to accomplish the same result.

It had also occurred to him that an apparatus of this kind might possibly be contrived on the principle of the Dalen "sun-valve." This valve was employed with acetylene buoys and was constructed to turn off all but the bye-pass during the day, but to turn the cock full on at night, in this way leading to a very considerable saving in gas. The principle of the valve depended on the unequal expansion of two cylinders, one highly polished and one coated with dead black material. It was stated that in this way one secured an apparatus which responded to light rays but was practically unaffected by radiant heat.

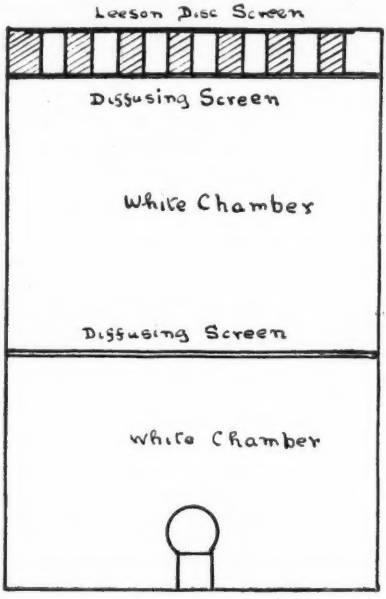
In conclusion, Mr. Gaster referred to the interesting contributions describing the work being carried on in the United States on selenium and photo-electric cells, and thermopile measurements, and thanked the gentlemen concerned for the trouble they had taken in putting this information at the disposal of the meeting. No doubt this discussion would stimulate interest in the subject, and would, he hoped, lead to further advances in the measurement of light and illumination.

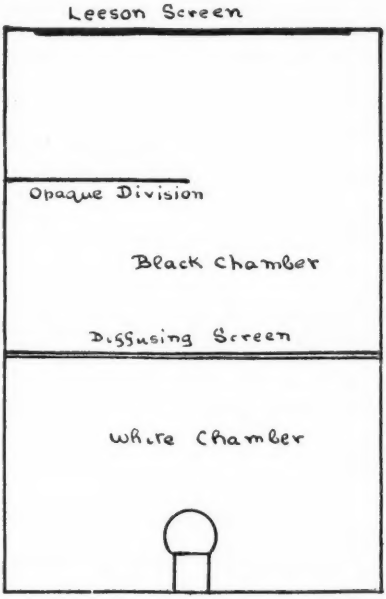
MR. J. S. DOW (*communicated*):—It occurred to me that it would be of interest to describe two forms of photometers which were experimented with by Mr. Mackinney and myself some time ago, but, chiefly owing to the disturbance caused by the war, have not yet been developed to a practical stage.

One of these (see Fig. 1) may be termed a "cell-photometer," and is designed on very similar lines to that suggested by Mr. Cunnington. The lamp, in a dead-white chamber, produces an even illumination over a sheet of diffusing glass or celluloid. This surface becomes an illuminating source and illuminates a second white chamber. (This diffusing screen seems desirable in order to produce even illumination and diminish the light, but is not strictly necessary.) The even illumination in the upper white chamber lights up a second diffusing screen, which might be of flashed opal or ground glass. This is placed below a slab of white vulcanised fibre, in which a series of holes have been drilled. Above this slab a Leeson disc screen is arranged, the circular apertures being each above the corresponding hole. Thus each hole becomes an evenly illuminated cell lighting up the disc immediately above it. The intensity of the illumination in each hole can be graded by obscuring more or less of the translucent surface immediately under it. Thus we can arrange that a series of six small discs disappear at illumination of, say, 0.1, 0.5, 1, 2, 5, and 10 foot-candles. By having an exactly similar series of holes, but placing beneath them a suitable dark glass or strip of opal glass cutting off one-tenth of the light, we can secure an additional low scale with readings of 0.01, 0.05, 0.1, 0.2, 0.5 and 1 foot-candles.

Another way of meeting the problem is shown in Fig. 2. In this case the even illumination of a diffusing glass screen is again produced by a lamp in a white chamber. But the upper chamber is now black. It contains an opaque division running transversely across and dividing it in two so that, at the left top corner of the box the diffusing screen is entirely

obscured, while at the right top corner it is entirely visible. As a result the illumination on the screen at the top falls uniformly from a prescribed value of illumination (say 10 foot-candles) to nothing.





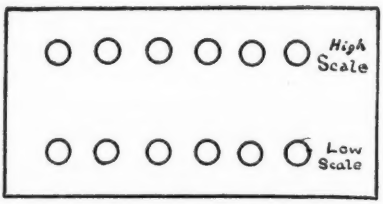


FIG. 1.—Scheme for portable illumination photometer of the "cell-type," requiring no manipulation to obtain a reading (Mr. J. S. Dow).

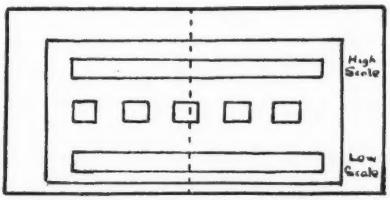


FIG. 2.—Scheme for portable illumination photometer, with graded scale requiring no manipulation (Mr. J. S. Dow).

The screen is conveniently made on the Leeson principle. It may consist of a slot in a thin piece of cardboard, having on either side a thin sheet of tissue paper, and, as in the case of the other instrument, a lower scale of one-tenth the value could be obtained by placing suitable obscuring material under a second slot. The idea of this instrument was suggested to me by a simple apparatus shown at a meeting of the Society by Mr. Haydn T. Harrison some years ago.*

I found, however, that it is not easy to determine the precise point where the slot changes from "bright" to "dark"; the transition is too gradual. It therefore appears necessary in such instruments to have a series of discs or squares so that the surface to be judged is com-

* *Illum. Eng.* Vol. III., 1910, p. 373.

pletely surrounded by the other one with which it is to be contrasted.

In both the instruments described above, one aims at obtaining a reading by mere inspection, and without having to manipulate anything to obtain a balance. In this way one approaches nearer to the principle of a direct reading electrical watt-meter, while an ordinary photometric instrument might be compared with a Siemens dynamometer.

As regards the question of making instruments of the "extinction" type, it is possible that such apparatus might furnish rough indications in cases where comparisons are made between lights of the same colour, or of the illumination yielded at various points by one and the same lamp. But in comparing sources which differ in spectrum composition it seems a wrong principle to take measurements at the extinction point where the eye is in an entirely different condition from what it is at ordinary illuminations. This matter deserves further study; it would probably be found that such methods favour unduly lights which have a pronounced green-blue element in their spectrum.

The observation of fine type introduces difficulties arising through variation in the acuteness of vision of the observer. Possibly such difficulties might be mitigated by employing *observation of contrast* which seems likely to vary to a less degree than *perception of form*.

The CHAIRMAN thought the subject of the discussion had been justified by the results. There had, he said, been some very interesting communications read and some most useful and valuable contributions from the speakers in the discussion. It seemed to him that we should realise very fully the necessity of having some reliable form or forms of portable photometers if we are to see the introduction of low illumination readings as the determining features regarding the performance or non-performance of street lighting contracts, and the compliance or non-compliance with statutory requirements in factories and workshops. We did not yet feel sufficiently certain that the portable photometers on the market could be relied upon with such a degree of accuracy within a small or reasonable margin of error as to provide the basis of a contract containing a penalty clause. At any rate he himself did not feel this and he did not think that many who were acquainted with the subject of illumination felt any certainty either. It had been quite truthfully said that it was impossible to carry the laboratory about in streets or in factories and it was necessary to be sure that results were obtained from portable instruments which closely approximated to laboratory tests. It was very good news to hear from Mr. Walsh that the National Physical Laboratory when war broke out were carrying out research in the direction of photometers depending on physical and chemical methods, but naturally they could not be expected to carry on this work during the war. Obviously the ideal was a physical and not a physiological determination of illumination, so that there could be no question of dispute through the introduction of the human error.

INDUSTRIAL ILLUMINATION.

We notice in the *Bulletino dell' Ufficio del Lavoro* (the official publication of the Italian Ministry of Agriculture, Industry and Commerce) a reference to the Report of the Home Office Departmental Committee on Lighting in Factories and Workshops in this country. The writer recalls the steps leading up to the issue of this Report, including the important place assigned to good industrial lighting at the Brussels Congress in 1910. The Italian Government have taken a prominent part in encouraging the research into industrial hygiene, and it is interesting to observe that they are fully informed as to the steps being taken in this direction in England.

NEW ADDRESS.

R. C. Bussell (Director of Blanchard British Lamps, Ltd.), 13, Haverstock Hill, London, N.W.

SUMMARY OF DISCUSSION.

For the convenience of members we give below a summary of the chief suggestions made in the course of the discussion printed *in extenso* in the preceding pages. The suggestions of the various speakers and contributors are arranged, as far as possible, under the heading of the respective inquiries (see p. 80) to which they refer.

(1) *What possible methods can you suggest for making illumination photometers of the ordinary type (i.e., those involving the use of a comparison source of light) more convenient for the use of the general public?*

Mr. Trotter (p. 84) expresses doubt whether "the general public" should be encouraged to amuse themselves with illumination photometers. Some experience is necessary. Mr. Cunnington, however (p. 89), thought that the difficulty of taking photometric observations is apt to be exaggerated and that simplification of the process might be encouraged. The Chairman (p. 100) pointed out the need for thoroughly reliable instruments for use in determining features regarding the performance or non-performance on contracts, especially those involving a penalty clause. For such work accurate apparatus was essential, even though this might involve some greater complexity.

Favourable experience with instruments of the luxometer and lumeter type is recorded. The chief source of difficulty is the fact of the battery gradually running down if the instrument is used for long periods. Dr. Marchant suggests that a device automatically correcting for change in voltage might be incorporated in the instrument (p. 85). Mr. W. R. Cooper (p. 97) pointed out that if a voltmeter were used, it should be exceptionally accurate. Mr. Cunnington did not find this difficulty of falling P.D. serious, but sometimes found it convenient to make a correction from a voltmeter reading. He thought, however, that such instruments should be simplified and that, for ordinary experimental work, no attempt should be made to make the user "independent of a laboratory," if this implied undue complexity.

One direction of experiment would be to produce instruments which could be read on inspection, without it being necessary to manipulate the parts to obtain balance. A form of "box-photometer" on this principle is described by Mr. Cunnington (p. 90) and other attempts in this direction are mentioned by Mr. Dow (p. 99). Mr. J. M. Trezise (p. 91) describes a new form of photometric screen, utilising a piece of white glass which is cut with a diamond and inclined at a suitable angle. This proves to be extremely sensitive. The screen has been embodied in various very compact forms of instruments, which are described. The apparatus can be compressed within very small dimensions by using a small lamp, placed veryn ear to the illuminated screen.

Lieut. Haydn T. Harrison (p. 84) objects to the use of an eyepiece; the photometric screen should be viewed with both eyes. Mr. Walsh suggests a form of absorbing screen made by scratching fine lines on a glass coated with black varnish.

(2) *What are the prospects of making a satisfactory instrument depending on :—*

(*a*) *The principle of "extinction," i.e., diminishing the illumination to be measured until some small object just becomes invisible to the eye ?*

(*b*) *The observation of fine type—a minimum illumination being indicated by the fact of fine type becoming indistinguishable when viewed by the prevailing illumination at the point studied ?*

Mr. Trotter (p. 84) expresses the view that physiological difficulties render all methods of "extinction" and "minimum visible" misleading. Dr. Marchant (p. 85) thinks that instruments depending on acuteness of vision have very small prospect of accuracy. Lieut. Harrison (p. 85) does not favour measurements by observation of type, owing to variation in the acuteness of vision of observers. Instruments based on extinction can be contrived but the colour difficulty should be considered, and such instruments are probably only applicable when comparing lights of similar colour. The same view is expressed by Mr. Dow (p. 100), who adds that if such principles are used as a rough guide, observation of contrast would probably be preferable to perception of form. Mr. Cunnington (p. 91) has contrived an apparatus based on the latter principle, but so far has not got any reliable results.

(3) *What are the prospects of making a satisfactory instrument depending on the following physical or chemical methods :—*

(*a*) *The use of selenium or other photo-electric cells.*

(*b*) *The use of thermopiles or other instruments for measuring radiation with or without a suitable solution or screen for absorbing the non-visible rays.*

(*c*) *The difference in expansion of two metallic elements, one polished so as to reflect a maximum of visible light, the other coated with an absorbent mat black material, but otherwise similar.*

(*d*) *The use of photographic methods such as the darkening of light-sensitive paper.*

(*a*) Recent work on selenium and other photo-electric cells is summarised by Mr. Dow (pp. 81, 82) and by Mr. Walsh (p. 94). Reference is made to the effect of fatigue, the variations in the behaviour of different cells, and to the fact that the relative sensitiveness throughout the spectrum of selenium cells alters according to the illumination. Information on these points is also furnished by Mr. Cooper (p. 97).

Mr. Addenbrooke has found that impurities exercise an important influence on selenium (p. 97), but this is not Mr. Cooper's experience (p. 97). Selenium was used in a form of portable photometer by Torda many years ago, the instrument being provided with an automatic shutter to avoid the effect of fatigue (Mr. Gaster, p. 98). Mr. Turner has applied it to enable lamps to be automatically extinguished in daylight and lighted up in the evening, and it has been used in a similar purpose in factories (p. 98). Mr. Cooper also mentions the use of selenium cells as "detectors" in this way, but thinks that at present the various difficulties enumerated above prevent its successful use for photometry. However, improvements in the preparation of such cells may lead to an advance in the future.

The Elster and Geitel cell is described by Mr. Walsh (p. 94) and referred to by Prof. Féry (p. 88) and Dr. Ives (p. 87), who mentions some recent work having for its object the preparation of cells for which the relation between illumination and response

is a straight-line law. Attempts are also being made to achieve uniformity as regards sensitiveness to light of different colours, in which case the photo-electric cell might prove a reliable and highly sensitive method of measurement. At present, however, it is essentially an apparatus for laboratory use.

(*b*) Mr. Dow describes recent instruments due to Ives for measuring light depending on the use of thermopiles (p. 83), and this subject is also discussed by Prof. Féry, who has evolved an apparatus of this type. Such instruments use either a cell of special solution to absorb the non-visible rays and correct the sensitiveness throughout the spectrum so as to produce what is equivalent to an " artificial eye" ; or a similar correction is applied by means of prisms and a suitable screen cutting down the radiation at each point in the spectrum in the desired proportion.

Still more recent experiments are described by Dr. Ives (p. 87) and Dr. Coblentz (p. 87).

It is hoped to increase the sensitiveness of such instruments by some form of current amplifier on the lines of those developed for wireless telegraphy.

Mr. Waldram (p. 85) points out the close resemblance between the curve of solar radiation obtained by physical instruments at the Meteorological Office and similar curves obtained with a photometer showing the variation in daylight throughout the day. Mr. Whipple reproduces a typical curve obtained by physical methods at South Kensington (p. 96) and describes a number of instruments used for measuring solar radiation ; these may have some application to photometric problems.

Experience seems to show that at present an instrument measuring radiation as heat, and corrected by prismatic means or by using a cell of special solution, affords the most accurate and hopeful method of measuring light by physical means. A high degree of accuracy has been obtained in the laboratory, but the refined nature of the apparatus and the small electric currents to be measured at present seem to impede the use of this method in portable illumination photometers. Moreover, in any case they involve the use of a battery, which is the chief difficulty in illumination photometers of the ordinary kind.

(*c*) A suggestion on this point is made by Mr. Gaster (p. 98) who remarks that the principle used in the Dalen solar valve for use with acetylene buoys might possibly be applied for the physical measurement of light. This apparatus depends on the unequal expansion of two elements, one highly polished and one coated a dead black, and is used for the automatic turning off of acetylene lights when in full daylight, the flame being turned on again when darkness falls. The application of the method to photometry requires further investigation.

(*d*) Photographic methods are referred to by various speakers (Mr. Dow, p. 82 ; Mr. Harrison, p. 85 ; Mr. Waldram, p. 85 ; Prof. Féry, p. 88).

It is pointed out that the relative sensitiveness throughout the spectrum differs considerably from that of the eye and varies according to the chemical material used. Therefore, while the method may be used for relative work, it is not readily applicable to the comparison of illuminants which differ in spectrum composition. Moreover, as a rule the use of photographic methods is tedious in comparison with the ease with which an ordinary illumination photometer can be handled. One special advantage of photography, however, is its integration of light-effects with respect to time. It may, therefore, have applications for testing fluctuating and very transient light-effects.

(4) *What instances can be quoted of the above principles being used successfully in other fields of photometry, for example, in records of daylight, meteorological observations, determining polar curves, observing fluctuations in the light given by various lamps, &c. ?*

Lieut. Harrison refers to the use of photographic records of testing periodic fluctuations in the candlepower of flickering light-sources, and the deposits on the bulbs of incandescent electric lamps. The method has also been experimented with for tracing polar curves of light-sources. For this latter purpose thermopiles have also been used.

Photography has also been applied in dealing with very faint lights, for example in researches on the quality of light yielded by fireflies.

It is also suggested that some of the above methods, while not yet applicable to portable illumination photometers, would be of value in laboratory work on standards, &c., where minute changes in candlepower are being studied, and a check on personal observations by some method independent of physiological errors is therefore desirable.

(5) *Are you aware of any methods which could conveniently be employed in the design of instruments to indicate automatically when the illumination in an interior has fallen below a prescribed minimum, and an increase in the illumination is therefore necessary ?*

Three cases are mentioned, the use of Turner's selenium apparatus for automatically extinguishing and lighting street lamps (p. 86); the use of selenium cells for indicating the time when artificial lighting is needed in factories (p. 98); and the use of the Dalen Sun Valve for automatic control of acetylene buoys. But little has been published regarding the accuracy with which such apparatus can be made to operate at a particular value of illumination

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RESEARCH ON PROBLEMS OF INTEREST TO THE LIGHTING INDUSTRY.

With a view to considering the organisation of research on problems of interest to the lighting industry, a Committee of the Illuminating Engineering Society has been formed, and will issue a Report on the subject for consideration at the Annual Meeting of the Society, to take place at the House of the Royal Society of Arts at 5 p.m. on Tuesday, May 9th This discussion will follow immediately after the conclusion of formal business.

Meantime members are invited to send in to the Hon. Secretary (Mr. L. Gaster, 32, Victoria Street, S.W.) any suggestions for research which might profitably be supervised or undertaken by members of the Society, and these suggestions will be submitted to the Committee in due course.

A YEAR'S PROGRESS IN ILLUMINATING ENGINEERING.

A Report presented by the Committee on Progress (Mr. F. E. Cady, *Chairman*, Mr. T. J. Litle, Mr. L. B. Marks, Mr. T. W. Rolph), at the Ninth Annual Convention of the Illuminating Engineering Society, held in Washington, September 20th to 23rd, 1915; slightly abbreviated.

(*Continued from Vol. VII.*, 1915, *p.* 450.)

The Panama-Pacific Exposition.

In its use of light the Panama-Pacific Exposition furnishes the most striking example of the progress of illuminating engineering that has ever been presented. It is an almost complete report in itself. For the first time in the history of such institutions a recognised illuminating engineer has been called in to take care of that branch of the work. For the first time in history the lighting of an International Exposition was completely designed and chartered before the buildings were erected, and the results bear eloquent testimony to the wisdom of that action. The latest types of street lighting both gas and electric are represented; the exteriors of the buildings are brilliant with "flood lighting"; the lighting of Festival Hall is a unique exampl of totally indirect lighting; display lighting is exemplified in the wonderful scintillator system and in the Tower of Jewels; efforts to avoid glare are manifest on all sides; never has there been a more lavish use of coloured light. And so this exposition stands as a living witness to the fact that illuminating engineering has "come into its own."

No attempt will be made to discuss all the novelties to be found in the lighting effects but reference will be made to some of the more prominent features of the illumination. More complete descriptions will be found by reference to the partial bibliography.[85] The basic idea back of the general illumination of the buildings was the desire to present the exposition at night in the same relative values of colour and perspective in which it is observed by day. On this account the old outline-system of illumination in which incandescent electric lamps were used to outline the architectural features of the buildings was abandoned in favour of the new flood-lighting idea and particular attention has been paid to the ocular comfort of the sightseer while at the same time displaying for his appreciation wonderful effects produced by artificial light.

Four principal methods of illumination are employed. Opposite the walls of the exhibit palaces are luminous art standards bearing transparent shields, through which light is thrown on to the fascades. A second method of illumination is found in the concealed batteries of searchlight projectors which are used to flood the monumental sculptures, towers and minarets so that the minutest architectural details are visible. A third source of lighting is that of the concealed light which proceeds from the inner recesses of the columns which encircle the courts or are placed on the lofty Tower of Jewels and the Italian Towers commanding the entrance to the Court of Palms and the Court of Flowers. This method of lighting is also used in the vaults of archways and in other situations where it is desired to cast light upon the mural paintings. The great battery of 48 searchlight projectors each with a 36-in. (91.44 cm.) lens forming the "scintillator" makes a fourth source of illumination.[86]

In addition to these four principal sources of lighting there are several minor sources. In various parts of the grounds are globes of white glass the light from which, at night, dissipates the shadows under the foliage. In the great central Court of the Universe two lofty columns of dense white glass are parts of the two

[85] *Light. Jour.*, Mar., 1915, p. 49.
Elec. World, Feb. 13, 1915, p. 391.
Elec. World, May 29, 1915, p. 1383.

[86] *Sci. Amer.*, Apr. 24, 1915, p. 378.

fountains and are the principal source of the night illumination of the Court.

The striking effect of the Tower of Jewels was obtained through the use of specially designed[87] jewels cut from glass obtained in Bohemia and having an index of refraction of from 1.68 to 1.71. Each gem is suspended so as to be free to swing with air currents and has a little mirror placed within one-sixteenth of an inch of the apex, thereby increasing the number of spectra obtainable.

A noteworthy feature of the highway lighting is the use of 18 to 24-in. (60.96 cm.) globes carrying glassware of an absorption of approximately 50 per cent. and of a warm opal tint approaching amber. The illumination of the interiors of the buildings is accomplished by the use of 250 and 500-watt tungsten lamps in specially designed mirror reflectors. The lamps are located from 40 to 100 ft. (12.19 to 30.48 m.) above the floor, the energy is less than 2 watts per square foot (9.29 sq. dm.) and the foot-candles range from $\frac{1}{2}$ to $\frac{3}{4}$ on the floor.

The first commercial installation of high pressure gas lighting in this country[88] and one which is said to show many improvements over foreign practice is to be found in the State and Foreign Building Section. The main artery for traffic is the Avenue of Nations and this and other streets and avenues in this section are lighted by high pressure two-mantle lamps enclosed in opal globes mounted single on the top of ornamental staff work columns. The lamps consume 21 cu. ft. (5.94 m.^{3}) of gas per hour, operate at 3 pounds (1.36 kg.) pressure, reduced at the standard from 30 pounds, and have a mean spherical candlepower of 408.

Installations of the same lamps have been made at all the entrances and exits of the grounds. At the entrances and exits of the main group of exhibition palaces and at the entrances of the courts, lamps of the low pressure type are used, mounted on brackets. In the "Zone" gas standards 35 ft. (10.66 m.) high are placed at intervals of 100 ft. (30.48 m.) on both sides. There are 72 of these standards each carrying 5-mantle lamps with mercury valve distance control. Large decorative lanterns are hung about these lamps. Decorative effects[89] are obtained by the use of gas to produce tongues of flame from serpent-headed urns.

Some very spectacular effects are obtained[90] in the lighting of the glass dome of the Palace of Horticulture. These effects are made possible by the use of sets of specially designed lens plates, colour screens and high-powered searchlights. The system used in lighting the interior of Festival Hall is a separate and distinct type of interior lighting which is unique. In a pit beneath the centre of the floor are placed a number of searchlights which are set to throw their beams upward into a diffusing disk of thick glass sand-blasted on the under side, which distributes the light over the dome covering the auditorium and the dome in turn acts as a diffusing reflector.

The most bizarre and spectacular phenomena are produced by the "scintallator," over 300 effects having been worked out.

At the San Diego Exposition[91] neither the "flood-lighting" nor the "outline" system of illumination is used, but ordinary street lighting supplemented by light from the arches of the arcades. This has been found very satisfactory.

[87] *N. E. L. A. Bul.*, Apr., 1915, p. 250.
[88] *Amer. Gas Light. Jour.*, Nov. 30, 1914, p. 349. *Jour. of Gas Light.*, July 6, 1915, p. 17.
[89] *Gas Inst. News*, Aug., 1915, p. 343.
[90] *Elec. Rev. and W. E.*, June 5, 1915, p. 1032. *Sci. Amer.*, Feb. 20, 1915, p. 180.

(*To be continued.*)

SUBMARINE SEARCHLIGHTS.

A recent issue of *Popular Mechanics* contains several articles describing special applications for searchlights during the war.

The first of these describes a method, developed by an American, to locate submerged mines. A powerful enclosed searchlight is mounted under water to one side of the vessel and near the bow. Slightly above the searchlight there is a periscope mirror arrangement, enclosed in a tube coming up to the deck, through which, it is claimed, the observer can see any object illuminated by the searchlight beam at a distance as great as 2,000 feet,

TOPICAL AND INDUSTRIAL SECTION.

[At the request of many of our readers we have extended the space devoted to this Section, and are open to receive for publication particulars of interesting installations, new developments in lamps, fixtures, and all kinds of apparatus connected with illumination.

The contents of these pages, in which is included information supplied by the makers, will, it is hoped, serve as a guide to recent commercial developments, and we welcome the receipt of all *bona-fide* information relating thereto.]

BRITISH-MADE GLASSWARE.

DISPLAY AT THE BRITISH INDUSTRIES FAIR, SOUTH KENSINGTON.

AT the British Industries Fair, held at the Victoria and Albert Museum, South Kensington, from February 21st—March 3rd, the exhibits included an interesting display of British-made glassware and pottery. Much of this was of an ornamental type of table use, cut-glass vessels being a specially well-represented section.

We were, however, also interested to notice the number of firms that are now supplying British-made glassware for lighting, as well as special glass vessels for scientific and chemical work. Among the suppliers of laboratory glass we note the names of the Edinburgh and Leith Flint Glass Co., Messrs. Molineaux, Webb & Co., Ltd. (Ancoats, Manchester) and John Moncrieff, Ltd. (Perth), while the section on lighting glass included exhibits from the following:—Messrs. A. M. Allan & Co. (Glasgow), Messrs. Burtles, Tate & Co. (Manchester), Messrs. A. & J. Davies, Ltd. (Stourbridge), the Edinburgh and Leith Flint Glass Co. (Edinburgh), "Glass Sundries" (London), Messrs. Greener & Co. (Sunderland), Messrs. Molineaux, Webb & Co., Ltd. (Ancoats, Manchester), and the New English Glass Manufacturers, Ltd. (Tipton).

The show of lighting glass was not very extensive in comparison with the large space devoted to domestic and table ware, but we were glad to notice several examples of special fancy shades, the manufacture of which had only been undertaken since the war. Another section of some interest was the manufacture of pavement lights and prismatic glassware for the direction of daylight in confined areas.

"LAMLOK" SPECIALITIES.

The Edison and Swan United Electric Light Co., Ltd., send us particulars of the "Lamlok" lamp locking lamp-holder. This holder can only be unlocked by the proper key, and thus gives the person in authority the complete control over all lamps on his circuit.

Such holders are of considerable utility in large installations in preventing unauthorised removal of lamps or substitution for existing lamps of others of an incorrect candlepower.

We have also to acknowledge the receipt of the latest show-card of the Company, bearing a cardboard representation of a man's arm carrying a Royal Ediswan lamp at arm's length.

ROBERTSON LAMPS.

A recent list of Robertson lamps contains particulars of many miniature and special patterns, candle lamps, &c. We notice particularly the tubular heating lamps having a special doubled and centrally supported filament, designed to secure even distribution of heat all over the bulb and therefore satisfactory life.

The leaflet also contains a view of the Glass Works, Lemington-on-Tyne, and various views of lamp-making operations at the Osram-Robertson Lamp Works.

"OSRAM" RELIABILITY.

The General Electric Co., of China, Ltd., Shanghai, report that they have for the sixth time been successful in securing the yearly contract for the supply of Osram Traction type lamps to the Shanghai Tramways. This contract was secured in face of competition from the suppliers of many other makes of lamps.

HOLOPHANE ELECTRIC LIGHT FITTINGS.

At the present time the manufacture of glassware for the lighting industry is receiving a considerable amount of attention in this country. On the outbreak of war it became apparent that we were dependent to a great extent on supplies from abroad. It is therefore gratifying to note that Holophane glassware, even before the war, was manufactured in this country, and we understand that since the war there has naturally been great activity with this work, some important new varieties—notably the metal-protected industrial units—being introduced.

However, the supply of suitable fixtures for such glassware is also important, and we have before us a recently issued catalogue of Holophane Fittings which deserves attention. The catalogue is excellently illustrated and contains a number of pleasing examples of fittings in various styles. Holophane glassware lends itself particularly well to use with somewhat massive fittings of an imposing type, and the bowl form is specially well adapted to ceiling units. The example shown on the opposite page illustrates a type in which the central bowl is combined with a series of pendant reflectors—a striking form of unit that deserves to be widely known. Presumably by a combination of this kind one could get effects as regards distribution of light that might not otherwise be easily obtained. Another illustration shows a typical hanging unit of the Excellite type for use with half-watt lamps, while the two-lamp bracket fitting shown in Fig. 3 is a pleasing form of unit for general lighting.

We may also mention the series of semi-indirect fittings for dining-room lighting. Amongst these we notice a type in which the semi-indirect unit is combined with pendant reflectors, thus giving at the same time a good general illumination and the requisite local lighting over the table. This seems a good way of meeting the special requirements of a large dining-room.

FIG. 1.—Holophane Excellite Pendant for Half-watt Lamps.

The semi-indirect bowl is in itself a pleasing object. But for those who admire illuminated silk shades it is worth noting that this unit can conveniently be screened by a silk canopy below. In this way the decorative effect of the silk is obtained and at the same time, owing to the fact that a great percentage of the light is reflected upwards, the loss of light is relatively small.

FIG. 2.—Holophane combined 16-inch stiletto bowl ceiling fitting with six reflectors.

FIG. 3.—Two-light bracket with Holophane globes.

Typical Holophane Electric Light Fittings for Interior Lighting.

INFORMATION ON INDUSTRIAL LIGHTING.

In view of the special attention given to this subject in our last issue, readers may be interested to refer to the special section which forms a feature of the *Electrical Engineer's Diary* (S. Davis and Co., St. Swithin's Lane, E.C.) for 1916, which was recently noticed in these columns.

Several of the aspects of factory lighting touched upon in our last number are fully treated in this special section, and we would draw particular attention to the tabulated list of requirements of various trades. Not only are the operations roughly classified as regards the amount of illumination needed, but suggestions are made for the correct spacing of lamps, the choice of local or general lighting, &c. In addition, hints are given as to the special problems to be met as regards discrimination of colour-values, correct shadow conditions, maintenance and cleaning. This last point is an exceedingly important one in many industrial installations, and it is worth noting that the loss of light occasioned by a few weeks' neglect may work out as high as 40 per cent. The money-value of the loss of illumination is frequently considerable in comparison with the cost of periodical cleaning.

GLARE AND THE STUDENT'S LIFE.

A recent article on this subject by Dr. James Kerr in *School Hygiene* draws attention to many points that have been studied by the Illuminating Engineering Societies in this country and in the United States. Dr. Kerr points out how visual acuity is readily affected by the glare from unshaded light sources, six distinct physiological effects being distinguished. He advocates that "*no naked filament, mantle or flame should be permitted, nor any source of light with greater intrinsic brilliancy than three candles per square inch.*"

In addition, the glare from highly-glazed and polished surfaces is apt to give trouble, and for school-books paper with a dull surface is strongly recommended. Dr. Kerr also refers to the need for establishing a standard of glare and mentions the instrument devised by Mr. A. P. Trotter for testing the qualities of different varieties of paper in this respect.

USE OF UNGLAZED PAPER FOR ILLUSTRATED BOOKLETS.

We are glad to notice that the *Edison Monthly* is now to be included in the list of journals printed on mat paper. As usual recent numbers of the *Bulletin* are well illustrated, and quite good effects are obtained from half-tone blocks.

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A LIGHT-SCREEN FOR USE IN WAR TIME.

We notice that a new form of screen for use with lamps in war time has been introduced by Messrs. Falk, Stadelmann & Co., Ltd. This "Diffusa" screen, we understand, consists of three conical metal rings placed one above the other with a view to obstructing the passage of light upwards in the manner required by the present circumstances and yet avoiding the production of bright spots of light below. The screen is applicable to outside lamps in streets, yards, &c. and can be used either with upright or inverted burners.

BRITISH COMMERCIAL GAS ASSOCIATION.

FOURTH ANNUAL REPORT.

The Fourth Annual Report of the British Commercial Gas Association has recently been issued. In view of the short time that the Association has been established its activity has surely been extraordinary, and its work furnishes one of the most remarkable examples of co-operative effort during recent years.

It is stated that the Association now embraces over 80 per cent. of the annual output of gas in the British Isles. Since the outbreak of war an enterprising policy of continuity of work has been adopted, and in many respects this work has been of real educational value. A special instance is furnished by the publicity given to the Home Office Report on Factory Lighting, the opportunity being taken to impress on all and sundry the benefits of good industrial lighting. As a result this valuable report has been made known to many people who would perhaps not otherwise have given it attention, and a stimulus has been given to the study of lighting in many factories which are working overtime on Government contracts and where, therefore, good illumination is of great importance at the present time

ANOTHER LARGE GAS-LIGHTED BUILDING IN THE UNITED STATES.

In our last issue we mentioned the Woolworth Building in New York, as a good example of a large interior lighted by gas on up-to-date lines.

We notice in *The Gas Age* for February 15th an interesting account of the lighting of the New Offices of the Consolidated Gas Co. (also in New York), which is interested both in gas and electric lighting. The illumination of the building is illustrative of this dual interest. The exterior is lighted lavishly by studded electric incandescent lamps, while the chief offices inside are illuminated with gas semi-indirect units, the fittings being of a massive and highly decorative character. Sixteen-inch and 24-inch bowls are largely employed, the latter containing two 5-mantle horizontal burners. The overall length of the fixture is 5 ft. 5 in., and the diffusing glass is selected to give a soft amber effect.

Another interesting point is the control of these gas units by electric ignition, the cock being opened and shut by an electro-magnetic apparatus and the gas ignited by a heated wire.